SH 4.2-13

# DETERMINATION OF GALACTIC COSMIC RAY LATITUDINAL GRADIENT USING EARTH BASED DETECTORS

Badruddin and R.S.Yadav
Space Science Group,Dept. of Phys.,A.M.U.,Aligarh(India)

ABSTRACT

Using cosmic ray intensity data of Deep River Neutron monitor and relation between solar wind velocity and heliomagnetic latitude,an attempt has been made to evaluate quantitatively the latitudinal gradient of cosmic ray intensity during the periods dominated by a two sector pattern.Assuming a constant orientation of the heliospheric current sheet on a time scale of the order of a year,arelationship is determined between the cosmic ray intensity and the heliomagnetic latitude.

I.Introduction. Galactic cosmic ray intensity gradients play an important role in guiding theoretical models of cosmic ray transport in the heliosphere.The behaviour of radial and latitudinal intensity gradients with time and heliocentric radial distance is of interest for the overall understanding of the cosmic ray modulation.Most of the earlier studies of latitudinal gradients were made with respect to heliographic equator or the ecliptic plane.However,with the realization of the importance of heliospheric current sheet,two recent studies(Badruddin et al.,1985;Newkirk & Fisk,1985)have addressed this problem by assuming the heliospheric current sheet to be the heliomagnetic equator.

In this extension,of our earlier analysis,we shall give a quantitative relationship for determing the heliomagnetic latitudinal gradient at IAU during a period (1974) dominated by two sector pattern.

2.Method. We have calculated the heliomagnetic latitude($\theta$) using the relationship,given by Zhao and Hundhausen(1981), between the solar wind velocity and heliomagnetic latitude both before and after the earth's crossing of the heliospheric current sheet (sector crossing),assuming the minimum velocity near the current sheet.Thus knowing the heliomagnetic latitude on days before and after the sector crossing. the latitudinal gradient of cosmic ray intensity with respect to zero latitude is calculated.Since the heliospheric current sheet(sector boundary) is thought to constitute a basic 'plane' of symmetry (Smith and Barnes,1983),the distance of the observations above or below the current sheet was considered more appropriate to a search for latitude dependence than the distance from the solar equator.

3.Results and Discussion. In Fig.1 we have shown the average latitude gradient in 1974 with respect to heliomagnetic equator, which we have assumed to be the heliospheric current sheet.We have not considered the solar rotations in which there was any sharp increase or decrease of cosmic ray intensity.It can be seen from Fig.1 that the cosmic ray

intensity decreases as the heliomagnetic latitude of the earth from the heliospheric current sheet increases. The relation between the gradient and the latitude for I974 can be expressed as:

$$G_{\theta}\ (\%) = -0.036\ |\theta| \qquad \text{for } 0^{\circ} \leq |\theta| \lesssim 30^{\circ}$$

Further, the maximum gradient from -I% to -3% has been found in different solar rotations.

The heliomagnetic latitude determined on different days using the relation between the solar wind velocity and heliomagnetic latitude (Zhao & Hundhansen, I98I) before and after the sector crossing and the corresponding gradient in cosmic ray intensity and solar wind velocity variations are shown in Fig.2. It is seen that during this period the cosmic ray gradient closely follows the solar wind velocity which increases away from the current sheet. The presence of such a latitudinal gradient of cosmic ray intensity indicate that some of the time variations observed at the earth are caused by the spacial variation of solar wind velocity with respect to heliomagnetic latitude (current sheet). Hakamada and Munakata (I984) suggested that solar wind speed depend on the angular distance from the magnetic neutral line (current sheet) and does not depend on the heliographic latitude of the Earth.

Roelof et al. (I983) using the data from IMP-8 and the closely spaced Voyager-I and 2 spacecrafts found heliolatitudinal gradient in $\gtrsim 35$ Mev protons of $\sim 2\%$ -5% per degree in short lived (IO-30 days) structures, and I% -2% per degree in structures recurring over a few solar rotations. From an analysis of IMP-8 and Voyager-1 and 2 data from I972 through early I982, Venkatesan et al. (I984) concluded that, when corrected for radial gradients of 3% per AU, the intensity difference between either Voyager-I or Voyager-2 and IMP-8 was consistent with a heliolatitudinal gradient 0.00% per degree for $\gtrsim$ 70Mev protons. In another study, Decker et al. (I984) examined the integral cosmic ray intensities (proton energy $\gtrsim$ 70Mev) between Voyager-I and Voyager-2 in the 8-I3 AU helioradial range and over $3^{\circ}$- $16^{\circ}$ heliolatitude separation during the first I7 months of the cosmic ray recovery in I98I -82. These data are also cosistent with the heliolatitude gradient $\backsim 0$ to $-0.4\%$ per degree. They admit that this null result is apparently still at least cosistent with either model of Fisk (I976) or Kota and Jokipii (I983), however, due to non availability of the location of Voyager-I & 2 relative to the heliospheric current sheet a detailed comparision with either the Fisk or Kota & Jokipii model is not possible. A preliminary analysis by Lockwood and Webber (I984) using the 26 days average Voyager-I and 2 counting rate gives less than -0.I% per degree heliolatitudinal gradient during I981-82 period for more than 60Mev particles.

From neutron monitor observations in I975, Newkirk and Lockwood (I98I) found a value of about -0.04% per degree at 5Gev for latitudinal gradient. The theoretical prediction, including a warped current sheet yield about -0.06% per degree (Kota and Jokipii, I982). For I970-79 period the symmetric

latitudinal gradient away from the current sheet is estimated to be -.06% per degree (Newkirk and Fisk,1985) which is not much different from our estimate of $\simeq$ -.04% per degree for the year I974.

4. Conclusion: It has been found that the cosmic ray intensity decreases as the angular distance of the earth from the heliospheric current sheet( heliomagnetic equator)increases. During I974 (for solar rotations in which there is no transient decrease of large amplitude) the maximum(negative) gradient from -I% to -3% has been found in different solar rotations assuming the heliospheric current sheet to be the heliomagnetic equator.The relation between the cosmic ray gradient and the heliomagnetic latitude can be expressed as:

$$G_\theta\ (\%) = -0.36\,|\theta| \qquad \text{for} \qquad 0^\circ \leq |\theta| \leq 30^\circ$$

The presence of such a latitudinal gradient indicates that some of the time variations of cosmic rays observed at the earth are caused by the spacial variation of the solar wind velocity with respect to current sheet.It may be possible that it is the heliospheric current sheet and not the helioequatorial plane that is of physical signifcance when one is calculating the heliolatitudinal gradients of galactic cosmic ray(Venkatesan et al.,I984).Since the relation between cosmic ray intensity and the heliomagnetic latitude may vary during the course of a solar cycles, aclear picture of heliomagnetic latitudinal gradient will emerge when the precise knowledge of heliospheric current sheet position during different epoch of solar activity cycle is available .

5. Acknowledgement. One of the authors(Badruddin)acknowledges the financial support from C.S.I.R., New Delhi.

References

Badruddin,R.S.Yadav,and K.R.Yadav,Planet.Space Sci.,33,I9I,(I985).
Decker,R.B.,Krimigis,S.M. and Venkatesan,D.,Astrophys.J.,278, LII9,(I984).
Fisk,L.A.,J.Geophys.Res.,8I,4646,(1976).
Hakamada,K. and Munakala,Y.,J.Geophys.Res.,89,357,(I974).
Kota,J.and Jokipii,J.R.,Geophys.Res.Lett.,9,656,(I982).
Kota,J.and Jokipii,J.R.,Astrophys.J.,265,573,(I983).
Newkirk,G.Jr.and Lockwood,J.A.,Geophys.Res.Lett.,8,6I9,(I98I)
Newkirk,G.Jr.and Fisk,L.A.,J.Geophys.Res.,90,339I,(I985).
Roelof,E.C.,Decker,R.B.and Krimigis,S.M.,J.Geophys.Res.,88, 9889,(I983).
Smith,F.J. and Barnes,A.,Solar wind Five (Ed.M.Neugebaur) NASA Publ. 2280,52I,(I983).
Venkatesan,D.,Decker,R.B.and Krimigis,S.M.,J.Geophys.Res.,89, 3735,(I984).
Zhao,X.-P. and Hundhausen,A.J.,J.Geophys.Res.,86,5423,(I98I).

SH 4.2-13

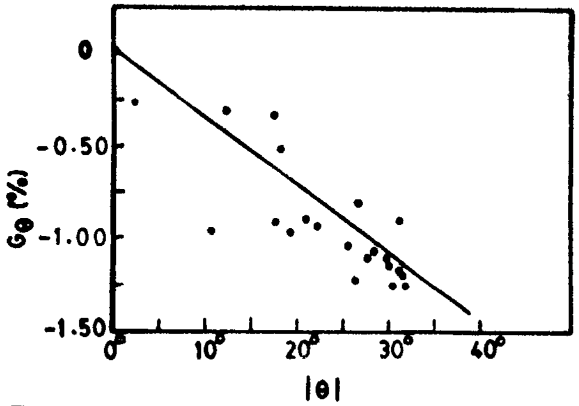


Fig..1

Fig.1 shows the average heliomagnetic latitude gradient calculated from Deep River neutron intensity for 1974.

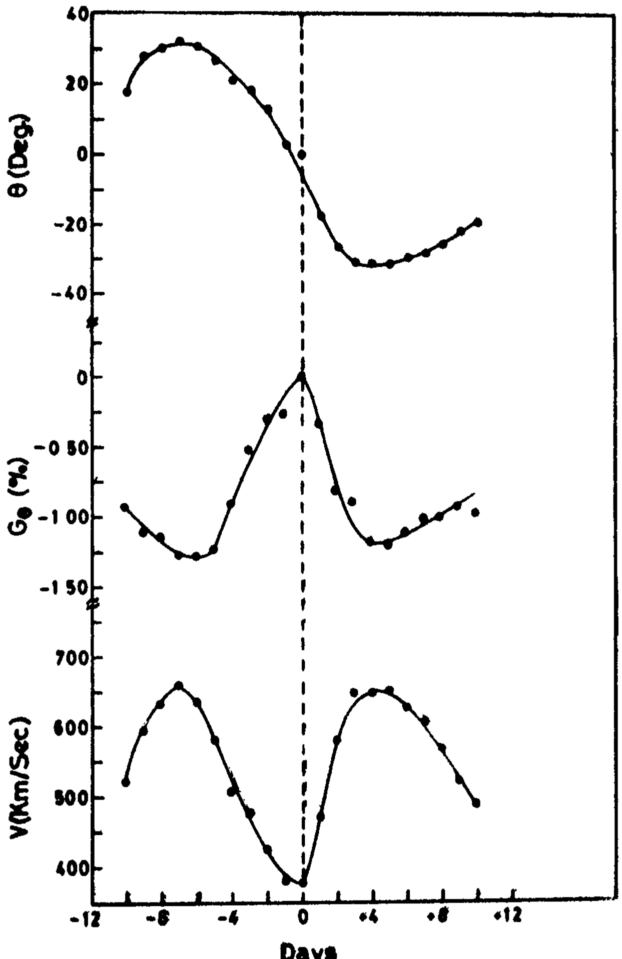


Fig..2

Fig.2 shows the variation of heliomagnetic latitude, the cosmic ray gradient and the solar wind velocity on the days before and after sector crossing for 1974.